# Design and change:
# A model of situated creativity

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## Abstract

This paper describes current research on the computational modeling of change phenomena in design. In particular it introduces a tutorial view of the model of *design situations* (DS) as a methodological basis for experimentation with change processes at the individual and the collective levels of an agent society. Creativity in the DS model takes place within the situated interaction of individuals in a social environment transcending its conventional characterization as purely a cognitive process.

## 1 Introduction

Creative design disciplines engage in the creation and transformation of key aspects of our environment. Buildings, everyday objects, and graphics, are continuously designed in order to satisfy the needs of large social groups. Such aspects are not restricted to the superficial appearance of artifacts but their configuration largely defines, constrains, and facilitates everyday experience. In turn, the socio-environmental conditions within which the design practitioners produce such solutions equally define, constrain, and facilitate their creative practice.

Societies delegate the shaping of their surroundings to a specialized minority that continuously seeks to address particular problems by generating new ideas. The type of problems approached, the solutions elaborated, and their impact, indicate a tension between individual and structure [Boudon, 1986]. Design is said to take place in the link that connects individual and collective change processes inasmuch as its practitioners aim to generate original solutions in response to perceived social needs. The products of this activity - design artifacts - may be subsequently manufactured, made available to, and collectively assessed by the social group. The experience of those who adopt the solution is often reshaped by these artifacts and every consecutive design process carried on may be affected by the social assessment of previous artifacts and designers. Lastly, subsequent evaluations of proposed solutions will be affected by previous generations and evaluations. In all, causation in creativity can be regarded as circular between micro and macro units of analysis.

Csikszentmihalyi [1990] has approached the study of creativity from a systems view where three dimensions are assumed to interact in the definition of creativity: a *domain* that transmits information to the person, a *person* who produces a variation which may or may not be selected by the field, and a *field* that in turn incorporates the variation into the domain. Whilst this approach coincides in that "there is no way to get evidence for a creative process taking place in a person's mind independent of social validation" the co-development of agency elements at different levels of analysis requires closer examination and experimentation.

In this paper we present a model called *design situations* (DS) as an alternative methodological basis in order to enable experimentation with the causal relation between change processes of design behavior at the individual and the collective levels of a society. To this end, Section 2 defines a view of creativity based on change and social influence. Section 3 introduces the notion of situational or situated creativity. Section 4 presents a situated view of agent-based modeling as an appropriate tool for experimentation. Sections 5 and 6 illustrate target change phenomena at the collective and individual levels respectively. These represent not exhaustive but illustrative phenomena from the literature. Results from preliminary models as proof-of-concept are discussed. Section 7 presents a view of the model of *design situations* where collective and individual change phenomena jointly determine creative behavior within the situation.

## 2 Creativity and Change

Creativity has been a research topic hard to define [Cropley, 1999]. A utilitarian view usually cites the complementarity of novelty and utility. However, once creative design activity is understood as an individual/structure tension system, such a dyad is considered a result of the micro-macro interaction and it becomes more appropriate to locate creativity at the individual or micro dimension of change. On the other hand, innovation refers to the corresponding collective or macro change process. In other words and for the purpose of this paper, creativity is defined as a feature socially ascribed to those whom generate a type of behavior and solutions that trigger a social change. The greater the change and the more elements of their society affected, the more creative an individual is regarded by the societal entity, i.e. as in H-creative figures [Boden, 1986].

Creative designers may therefore influence members of a social group who adopt their artifacts; they may also indirectly influence other existing and future members of the social group; and they may even influence other designers in the future generation of artifacts. This influence may take place within the designers' time or at a future time. Jørn Utzon is under this definition an example of a creative designer. The Sydney Opera House has had an impact not only on those who attend performances at the venue but has become an emblematic icon easily recognized around the world to represent an entire nation. Furthermore, this design artifact transformed coexistent construction techniques and has influenced the design of subsequent buildings [McLaughlin, 1993]. It consequently becomes of less relevance to try to objectively define the novelty or utility of this design artifact than to establish its influence in relation to socio-environmental conditions. Peer-recognition (another common defining criterion) may indeed reflect some aspects of this view of micro-macro co-development where a group, as a collective agency entity, assesses the novelty, utility, or any other component of creativity as it counts for members of that particular group at that particular time.

However, the principles of change within and between these agency levels are still largely unknown, in particular as related to design practice considering the ongoing debate and controversy around the definition of design creativity. Progress has been made in recent decades by a range of studies, mostly focusing on separate segments of this multivariate research topic in an isolated way [Edmonds and Candy, 1998]. These vary from individualistic approaches to personality traits and cognitive processes such as incubation and illumination to social dynamics of technology diffusion at the collective level. Such approaches have been conducted mainly through conventional research methods such as interviews, questionnaires, cognitive tests, field observation, and historical records [Runco and Pritzker, 1999] with fewer approaches focusing on the interdependent relationship between cognitive and socio-cultural entities [Findlay and Lumsden, 1988]. Due to the dominance of individualistic accounts of creativity, most computational models of creative behavior have targeted individual processes located in a social void [Langley et al, 1987; Hofstadter, 1994].

One of the current limitations is that research focused on individual traits has often produced contradictory results and paradoxes [Cropley, 1999; Gardner, 1993]. Reports encompass a wide-ranging set of frequently opposite characteristics displayed by people considered creative. To understand how opposite traits and behavior may yield influential outcomes it is necessary to take into account situated factors that reside outside the individual [Ross and Nisbett, 1991]. The research presented here aims to contribute to the modeling of creativity by extending the scope in order to integrate elements of change phenomena at both the individual and the environmental levels. To this end a methodological extension is necessary in order to conduct inquiry into the relation between the individual and its social group - the link where the concept of a *situation* lies. The emphasis on situated activity is essential to transcend the conventional characterization of creativity as simply a cognitive process or a set of cognitive operations attributed to a person [Finke 1996] often scrutinized largely isolated from context.

## 3 Situated creativity

The aim in developing computer models to synthesize or simulate behavior related to creativity and discovery [Langley et al, 1987] has been largely based on an implicit assumption addressed by attribution theory [Ross and Nisbett, 1991]. Empirical findings consistently point towards the Fundamental Attribution Error, i.e. that human observers tend to over-emphasize dispositional factors about the actor and under-emphasize situated factors. In particular, when confronted with what may seem exceptional behavior, people rapidly tend to associate this to extraordinary personal traits and attributes. A large part of creativity research is indeed concerned with the elucidation of such traits [Runco and Pritzker, 1999]. As a consequence, the conditions and details of the immediate context of behavior, the way in which the situation is construed by the actor and in general the interaction with the broader social context or social system within which the actors are functioning is undervalued. More pointedly, objective situated features and subjective construals that would make these seemingly exceptional actions less exceptional and more congruent are generally disregarded in the computational modeling of creative behavior.

Creative solutions - and individuals who generate them - are subject to collective ascription that takes place in response to changing group conditions. A creative product may seem surprising to the social group at first, to which only the product and not the generation process is available. Therefore post-factual attribution of behavior tends to conceal situated factors. Moreover, the effect of the situation may remain inaccessible even to creative individuals themselves if unaware of situated factors.

The assumption here is not that individual differences do not matter and that the creativeness of an outcome can be entirely attributed to situations [Sosa and Gero, 2002a]. Rather, the main aim of this paper is to draw attention to situated factors that have been largely overlooked and that may play a key role when considered together with individual characteristics in determining creative behavior. For instance, it is possible to address the notion of a *dangerous situation* in order to explain someone's behavior at a particular time. Such ascription applies to a set of objective social or environmental conditions within which individuals may find themselves as well as the way in which those individuals perceive such conditions. It is clear to see that in a situation regarded as dangerous the eventual behavior of an individual will be jointly determined by the personal traits, attributes, preferences, and choices of the person as well as situated factors. These situated factors may be out of control or only indirectly possible to control or choose by the individual in question and may have varying effects and degrees in shaping the outcome.

Whilst situations can indeed be characterized, as a unit of analysis they have remained unaccounted for in creativity research and we are unaware of any computational model that defines the role of situated factors in creativity. Arguably in some cases an individual alone determines the outcome but in others situated factors may account for it. What is necessary is a formal framework that enables experimentation. Studying a situated interpretation of creativity sets a different direction to current research methodologies. Such a direction must incorporate theoretical elements from social psychology and sociology in addition to those provided by cognitive studies of creativity.

## 4 Methodological Approach

An appropriate methodology or combination of methodologies should not commence with the notion of creativity as an individual cognitive faculty by which a person is regarded as *being* creative. Rather, an appropriate methodological stance should provide access to a process by which design practitioners *become* creative by the confluence of their actions and the conditions and actions of the environment. The process by which a product is generated and considered creative at a present time is sufficiently different from the process and the product that will be required at a future time to be considered creative. Even alleged creative designers are not exempt from generating failed solutions or from struggling to consistently produce creative outcomes [Gardner, 1993]. In sum, a methodology for the inquiry of creativity and innovation should not consider the study of *a priori* defined creative subjects or traits, but should allow observation into the processes by which a subject may gain and manage the role of change agent.

As a response to this need for an alternative methodological approach, in this paper we propose the study of change processes in individuals (i.e., agents) and in the collective groups that emerge from their interaction in a shared environment. The term *agent* is used as a modeling metaphor for autonomous individuals that execute behavior reminiscent of some aspects of human behavior [Gero and Brazier, 2002], and is defined in the literature as a program capable of flexible autonomous action situated in an environment in order to meet variable objectives [Wooldridge, 2000]. At least four elements are deemed necessary for this kind of behavior: timely and adaptive reactivity to a perceived environment and changes that occur in it; pro-active goal-directed behavior to take the initiative; social ability to interact with other agents; and situated learning by which the agent constantly revises its goals and behavior according to its experience within an environment. An agent system may be populated with homogeneous or heterogeneous agents depending on the difference of internal states and behavioral rules. Some states may be fixed for the agent's life-cycle while others may change through interaction with other agents or with the environment. The *environment* is defined as a medium separate from the agents on which these operate and with which they interact. From a social agent's viewpoint the environment includes contact with other agents.

Heterogeneity in the DS model is a way to account for different roles all concerned with complementary aspects of design such as: the generation of new artifacts, their diffusion, evaluation and adoption, individual preference, social influence, routinization, recognition and peer-judgment. As these types of behavior interact under specific social and environmental conditions, relevant processes that are expected to emerge include at the individual level the *becoming* of agents as: gate-keepers, opinion leaders, paradigm shifters, role models, early adopters, end-users, power users, laggards, etc. While at the collective level the target phenomena includes: community formation, cultural transmission, innovation cycles, product life-cycle, critical mass, etc.

Social agents are of obvious relevance for the study of creativity as a situated activity. Agent-based modeling is an alternative to conventional methodologies in the social sciences to formalize artificial societies where certain group structures and behaviors emerge from the interaction of individual agents operating under rules that place bounded demands on their information and computational capacity [Suleiman et al, 2000]. A range of collective phenomena relevant to creativity and innovation can be made to emerge from this interaction.

The departure point in social agent-based models contrasts with the aggregate perspective of macroeconomics and sociology, and can be characterized as 'methodologically individualist' [Epstein and Axtell, 1996]. Collective structures are not explicitly fixed but emerge during a system run and have feedback effects that alter the behavior of individuals.

Whilst mathematical and economic social sciences are also based on individual modeling and aggregation effects [Arrow, 1951] such models target predictable equilibrium states in populations of rational agents. For instance, conventional models of demand, pricing, income, and utility may provide a mathematical proof for statements such as "if demand varies but offer remains constant, then price and production move together whilst if demand is constant and offer varies, then prices will move inversely with production" [Arrow, 1951]. Note that the emphasis of an agent-based model is entirely different. The main aim is to provide insights into the complexity of change processes that define creativity and innovation in design through experimentation with simple local behaviors and how their interaction in time within certain environmental conditions may produce change structures that are largely unaccounted for as to date (i.e. regarded as inextricable genius at the individual level and as 'the invisible-hand' at the social level). It is contended that one of the best available ways to achieve this aim is to run the system and observe its behavior.

Agent-based modeling has been considered generative as opposed to deductive or inductive approach [Epstein and Axtell, 1996]. Agent societies can be regarded as empirical test-beds where certain macroscopic structures and collective behaviors of diffusion extracted from the literature are grown in the computer in order to discover the relevant local or individual design processes that are sufficient to generate them.

Nonetheless, conventional agent-based social simulation needs to be extended to include situated factors that support the circular causation of individual and group behavior. After presenting an overview of some of the target phenomena at the collective and the individual levels, research directions to model situated factors in creativity are presented.

## 5 Collective Change: Innovation

This section presents a number of collective phenomena that have been studied in the literature related to socio-environmental change processes. The main aim of this research is to link resemblant structures to the situated interaction of individual behavior.

### 5.1 Innovation and Convergence

Schumpeter [1939] characterized the nature of innovation as "a factor of change without which the *modus operandi* of the capitalist world cannot be understood". To elucidate the role of this essential component of an economic system he coined the term "creative destruction" to refer to the cycle that incessantly revolutionalizes the economic structure from within, repeatedly destroying an old one and creating a new one [Iwai, 2000]. If the aim to innovate is to destroy the stalemate of equilibrium by enabling a price rise above the prevailing cost or to lower the cost below the prevailing price, then profit turns out to be "the premium put upon successful innovation in capitalist society". Outside economic systems, the role of profit can be taken to any other factor that determines a comparative advantage such as performance or prominence. The key point is that the successful introduction of an innovation into the system makes it much easier for other people to do the same thing and thus a subsequent set of imitations will render the original innovation obsolete, gradually diminishing the innovator's advantage margin. This way, whilst imitation and group reliance push the group state towards uniformity, the recurring appearance of alternative values by dissenting individuals and the ensuing innovations disrupt the equilibrium tendency.

This initial conception of imitative and innovative co-dependence in a society coincides with the view of innovation as "an intrinsic value in evolution rather than an extrinsic parameter" [Findlay and Lumsden, 1988]. In design systems therefore, innovation should not be considered exceptional but an inherent mechanism of a broader social organization. Without each other, imitation and innovation have no significance; this co-dependence may be addressed by the specification of imitative behaviors that generate convergent structures and innovative behaviors that introduce divergence and change into the population or a segment of it.

### 5.2 Culture

The term *culture* is used here to refer to the convergent structures in an agent system that stand for the sets of beliefs and norms shared by a number of individuals regularly in a common time and space. However, the role of culture is still under debate and agent-based simulations can be utilized to inspect culture formation and its effects on individual behavior. It is often argued that at the core of culture formation, imitation mechanisms serve to avoid individual learning costs. Rogers [1989] has shown that in social learning the fitness of imitators declines as the frequency of imitators increases because the more imitators there are, the more poorly the population tracks environmental changes, and the lower the frequency of adaptive behavior. Therefore it seems that there always have to be some learners in a population. Boyd and Richerson [1995] have studied the benefits of culture formation for individual behavior showing that culture increases average fitness if it makes the learning processes that generate new knowledge less costly or more adequate. Culture may do this in at least two ways. Firstly, social learning allows individual learning to be more selective. Individuals can learn opportunistically when it is likely to be more accurate or less costly, and imitate when conditions are less favorable. Secondly, social learning allows learned improvements to accumulate from one generation to the next. Imitation can therefore lead to the cumulative evolution of behaviors that single individuals could not invent on their own [Boyd and Richerson, 1995].

## 5.3 Communities

In a postscript to his seminal work, Kuhn [1974] emphasized the importance of a single notion upon which his thesis rests: *communities* as the units that produce and validate knowledge.

A community is defined by Kuhn [1969] as a group of individuals bound by common elements in their education and practice, aware of each other's work, and characterized by the fullness of their communication and relative professional judgment agreement. A paradigm then is put forth as the set of shared elements that enables members of a community to solve problems and accounts for their relative unanimity in problem formulation and in the evaluation of solutions. Later called sociological paradigm or disciplinary matrix, this particular use of the term refers to the set of shared symbolic generalizations, shared models and values either implicit or explicit that characterize the discipline at some particular point in time. To investigate creativity in design it seems necessary to experiment with the notion of community formation and the change of shared elements across the design spaces built by different designers.

Communities may exist at different levels in a population depending on the number of subscribers, and thus a Kuhnian revolution is posed as a special sort of group change involving major reconstruction of shared commitments. The study of art and philosophy history also supports such notion of punctuated change of artistic style and taste or of philosophical goals and interpretations. In the arts the work that does not succeed in innovation is often described as *derivative* or lacking originality. Popper [1981] and others have challenged that a sociological paradigm renders some forms of activity normal, and the idea that *normal science* or practice is a corollary of the existence of revolutions. Inquiry into creative design requires experimentation with behaviors that may be differentiated between normal practice and revolutions as an instance of the co-dependence of innovation and imitation.

## 5.4 Diffusion

An innovation is defined as an idea, practice, or object that is perceived as new by a unit of adoption [Rogers, 1995]. *Perceived* novelty emphasizes that from a diffusion viewpoint an attempt to objectively measure novelty is inconsequential. An innovation-decision process includes amongst other steps: realization of a need for change; contact with an innovation; attitude formation; decision to adopt or reject; implementation and use of the new idea; and consequences of this decision. Rejection can be either active: considering adoption but then deciding not to adopt it; or passive or non-adoptive: never considering the use of the innovation. This process may be described both at the individual and at the collective levels by adjusting the appropriate unit of study, i.e. an agent or a community of agents.

Five general attributes of innovations include relative advantage, compatibility, testability, observability, and complexity. Innovations that are perceived by groups of agents as having greater relative advantage, as being more compatible, testable, observable, and predictable in its consequences tend to be more widely and rapidly adopted. Nonetheless, the power of subjective evaluation conveyed from other individuals who have previously adopted the innovation has to be acknowledged [Rogers, 1995].

An individual may be considered a *change agent* in relation to its ability to influence other agents' innovation-decision processes in a desirable direction. From a broad viewpoint, the role of change agents includes but is not limited to: identifying a need for change; diagnosing and formulating problems; establishing an information-exchange relationship; making available a solution that improves current state; translating change intent into action; stabilizing adoption; and preventing discontinuance.

The following types of innovation-decisions have been identified: optional, made by an individual independent of the decisions of the other agents; collective, made by consensus among various agents; authority, made by a relatively few individuals that possess power, status, or technical expertise; and contingent, made only after a prior innovation-decision [Rogers, 1995].

Individuals have been classified into adopter categories based on when they first begin using a new idea or artifact. The adoption of an innovation usually forms a normal, bell-shaped curve when plotted over time. When the cumulative number of adopters is plotted, the result is an S-shaped curve where the number of adopters per unit of time takes off once enough early adopters embrace a change and influence others acting as opinion leaders.

Earlier adopters are said to have greater empathy, greater rationality, higher aspirations, more intelligence, better to cope with uncertainty, and be less fatalistic. At the collective level earlier adopters also have more social participation, are more highly interconnected through networks, are more cosmopolite, have more change agent contact, greater exposure to mass media and personal communication, seek information, and higher degree of social leadership.

The transfer of ideas occurs most frequently between individuals who are homogeneous [Axelrod, 1997]. Homogeneity may occur due to proximity in a physical space or to common interests making communication more likely. However, the very nature of diffusion demands that at least some degree of heterogeneity be present since such network links connect communities and span sets of socially dissimilar individuals. Heterogeneous links are especially important in the spread of innovations as homogeneity may be frequent and easy but can actually act as a barrier to the spread of innovations within a population [Granovetter, 1973]

Critical mass is an emergent state at the collective level of the system that refers to an amount of adopters estimated large enough so that the innovation's further rate of adoption becomes self-sustaining across the population [Rogers, 1995]. A threshold is its counterpart at the individual level of analysis and refers to the perceived number of individuals who must become adopters before a given individual will adopt an innovation. An individual is more likely to adopt an idea if more of the other individuals have adopted it previously. Strategies for producing critical mass include: to target members at the top of the social hierarchy, to shape individual's perceptions of the innovation, to introduce the innovation to receptive groups and at adequate times; and to provide incentives.

Discontinuance is a decision to reject an innovation after having previously adopted it. Later adopters are more likely to discontinue innovations than are early adopters. Two types of discontinuance are replacement, in order to adopt a better idea and disenchantment, as a result of dissatisfaction with its performance. Routinization occurs when the innovation has become incorporated into the regular activities of the social group and the innovation loses its advantage [Rogers, 1995].

Consequences are the changes that occur to an individual or to a social system as a result of the adoption or rejection of an innovation. There are at least three classifications: desirable versus undesirable, direct versus indirect, anticipated versus unanticipated. An adopter's experience with one innovation obviously influences that individual's perception of the next innovation.

Change agents introduce innovations that they expect will have consequences that will be desirable, direct, and anticipated. But often such innovations result in at least some unanticipated consequences that are indirect and undesirable for the system's members. Especially in design where a new solution may address some annoyances of existing solutions, but more likely than not fails to address some others or adds new ones of its own [Petroski, 1996]. Many innovations in design cause both positive and negative consequences.

In a population, solutions that are shared by a number of individuals become standard and are mass-produced. This brings a notorious advantage in the reduction of costs in development, production, distribution, and communication, but may have negative implications for change at least in the initial stages until the change is absorbed and the benefits permeate the system and stabilize costs.

The previous subsections have described some change phenomena from the literature indicative of the macro-structures of interest in the study of situated creativity. Experimentation with the interaction of design behaviors has been commenced to target phenomena that resemble what is currently known about culture formation, innovations, and their diffusion in a society.

## 5.5 Preliminary Modeling

Agent-based models of culture formation have focused primarily on convergent structures [Axelrod, 1997] and to a lesser degree on the maintenance of diversity in minority groups [Latané and Nowak, 1997]. But design activities have been characterized as a minority of specialized individuals triggering divergent structures in the rest of the population. We have explored elementary cellular automata models of social influence to address this phenomenon [Sosa and Gero, 2002b].

Firstly, certain aspects of social convergence have been found to actually generate value diversity. There is in principle an implicit and necessary divergent process within convergent trends in large cultural spaces. Cultural diversity may thus increase as a result of value diffusion.

Secondly, these models show that the response of one differing individual to perceived routineness may be sufficient to trigger collective change through the same convergent mechanism that brings about group coherence. Therefore, the formation and transformation of communities may occur through a common process of social influence where the *status quo* is disturbed by the appearance of an alternative value around which the social group reassembles [Schumpeter, 1939].

This suggests that it is indeed possible, in principle, for an individual to trigger a social change and that in order to do this it is not necessary to invoke any special mechanism other than that used to account for group convergence and occasional individual disagreement. Although this is admittedly a simplified view of the dynamics involved in social change (particularly of the agent/structure relation) it points towards a number of insights in relation to innovation and creativity issues in design. For instance, when the eventual success of individuals that aim to change their society is separated from any explicit notion of utility it is suggested that the merit of widely-spread values across a social group is not necessarily correlated with the particular attributes of that value. In design disciplines this carries important implications, including the partition between quality and creativity. Whilst it is possible to describe and measure the former within the internal characteristics of a design artifact, explanations of the latter need to include the relation of the artifact to the socio-environmental conditions within which it operates. Thus, the creativity of a design artifact is not seen as a stable property but a temporal ascription that takes place in its interaction with other agency entities both at the individual and collective levels.

Moreover, in order to become influential, a creative designer would depend upon a collective process by which others are indeed influenced. Persistence or persuasion may thus be a more important trait to creativity than 'imaginative thinking'. The implication that influential people or ideas are not necessarily the best but could have been in the right place at the right time challenges one of the mainstream views of creativity. To any extent, socially-ascribed 'creative people' do shape their societies but are also product of social dynamics themselves.

## 6 Individual Change: Design Creativity

In this section individual-based components of change processes are drawn from the literature under the premise that to describe psychological mechanisms that shape social groups, it is necessary to account for a) how individual behavior shapes the cultural environment and b) how that environment conditions the behavior that people execute [Henrich and Boyd, 1998]. The following behaviors are described in terms of the four properties of autonomous agents, i.e. reactivity, pro-activity, sociality, and situatedness.

The drive to produce novelty and exert influence may be related to the multiple sources of motivation. Whilst some behaviors are genetically determined in an organism, others may be learned or depend upon social interactions or environmental conditions [Petri, 1991]. The term *incentive* describes a force that motivates behavior to either reach or avoid a goal. However, people do not necessarily work to obtain every incentive value. An incentive becomes a goal as the individual decides to spend effort in order to obtain it. Thus goals are active incentives to which people commit. Berlyne [1960] argued that novelty and uncertainty are intrinsic motivators because they increase the arousal level of the individual, who attempts to maintain an optimal arousal level. Novel or surprising stimuli motivate behavior if they provide a small change in arousal. Under this view motivation is activated when stimulus conditions are either too high (drive reduction) or too low (drive increase). However, motivation is a multidimensional phenomenon [Petri, 1991] that can be either intrinsic or extrinsic to the individual (reward), or in other words, inherent either to the individual or to the activity. Reward has been found to both increase and decrease creativity [Eisenberger et al 1999]. Because persons are rewarded more often for conventional than for creative performance in everyday life, reward has been found to increase creative performance only when current task instructions explicitly specify a positive relationship between creativity and reward. Both stimuli and reward specification may be emergent effects produced by the situated interaction of individuals in a population and are included in the study of situated creativity to account for feedback influence of design behavior.

Design is defined as the transformation of human needs and intent into an embodied object [Rosenman and Gero, 1998]. From this viewpoint, design translates concepts from the socio-cultural environment into the description of technical objects. A formulated design problem is a representation of the perceived social need and the search for a desired state which is not yet known how to be achieved.

Design problems have been characterized by the following properties recognized as exemplars of design activity [Goel, 1995]. Some of these characteristics include: lack of complete information at problem formulation; negotiable and fixed constraints; co-evolution of problem and solution spaces; problem reformulation; inter-dependency of requirements; ad-hoc decomposition of problem parts; no right answers only more or less appropriate as assessed by the target social group; input consists of information from different people, goals, and requirements; feedback is simulated during the design process and available only if and after the design specification is built and the artifact is incorporated into the environment; proposed solutions must address problems that existing artifacts solve and at least some of those that they fail to solve; the artifact is evaluated independently of the designer but previous instances may influence the assessment; personal preferences and choices determine the design process including the decision to halt the design process; and lack of deductive reasoning substituted by abduction.

A new design artifact will displace an existing one only if there is a perceived advantage. To achieve this, the designer needs to identify the shortcomings and failures of existing artifacts and generate a solution to those problems. No existing or proposed artifact can be flawless in time due to change processes in humans and the environment and the necessary compromise between conflicting factors [Petroski, 1996]. If a new artifact is perceived as overcoming one or more pressing disadvantages, then there is room for alternative solutions that may trigger an innovation.

On the other hand long-existing artifacts often become familiar and people tend to adapt to inconveniences associated with their use. For this reason, the designer is often required to be the first to perceive existing failures that once articulated into a problem-solution pair become immediately obvious to everyone [Petroski, 1996].

Change at the individual level presents common elements with its counterpart at the collective level. For instance, key fundamental conditions are identified for conceptual change to occur: dissatisfaction with existing conceptions; a new concept must be intelligible; it must appear initially plausible; and should suggest the possibility of a fruitful program [Vosniadou, 1999]. This mechanism is similar to the innovation-decision process at the societal level and can be used to experiment with explorative agent behavior.

The fixed definition of a creative agent profile is avoided since creativity is considered a system phenomenon rather than an individual one. However, variety, flexibility, and marginality can be initial parameters for experimentation [Csikszentmihalyi, 1997; Gardner, 1993; Runco and Pritzker, 1999]. Variety refers to the observation that people considered creative tend to display sets of behaviors regularly found in segregation. Flexibility refers to the ability to switch across different behaviors in response to internal and environmental conditions. Marginality refers to asynchronous or dissenting behavior. Notwithstanding, these individual traits are related to adaptive behavior closely coupled to social and environmental factors.

This depiction from the literature is an indicative sample of the agent behaviors of interest in modeling situated creativity. Experimentation with the emergence of collective change structures will target mechanisms that resemble what is currently known about creativity in the design process.

## 7 Situations

The unit of analysis proposed here for the study of creativity is indeed the *situation*. A situation is defined as the modeling space built by the agent that includes the environmental conditions within which the agent operates. More specifically, a situation consists of the objective situated factors facing the agent as well as the agent's subjective construals of those factors [Ross and Nisbett, 1991]. The focus of this research is to characterize creativity at the situation level. Figure 1 presents the model of *design situations* where causation from an illustrative set of collective structures (top-down arrows) and causation from illustrative individual behaviors (bottom-up arrows) meet at the situation within which the behavior takes place. This differs from conventional agent-based modeling where only bottom-up emergence of group structures occurs. Whilst in most multi-agent systems behavior is entirely defined within the agents' behavior description, a situated approach suggests that agency exists at the group level too. One can see both collective and individual behavior as explicitly defined but it is only at their interaction space (i.e. the situation) that these combine and determine the behavior actually executed. The advantage of such 'online behavior determination' is that agents need not be predefined by the programmer at initial time as 'creative' or 'non-creative'. Rather, such ascriptions are assigned by their social group during a system run according to their behavior and impact on other agents.

Consider an exemplar case from social psychology: the Asch Paradigm [Asch, 1951]. In this type of experiments, individual choice is said to only partly determine behavior in a bottom-up direction whilst social pressure in the form of group unanimity exerts top-down causation. To Csikszentmihalyi's question [1997] as to where creativity might be, the model of *design situations* suggests that it is at the situation level. When individual differences are sufficient to determine creative outcomes, bottom-up causation is said to be determinant, whilst in other cases situated factors may largely account for an outcome through stark top-down causation.

Situated creativity refers to the process by which an individual builds and shapes its situation based on the

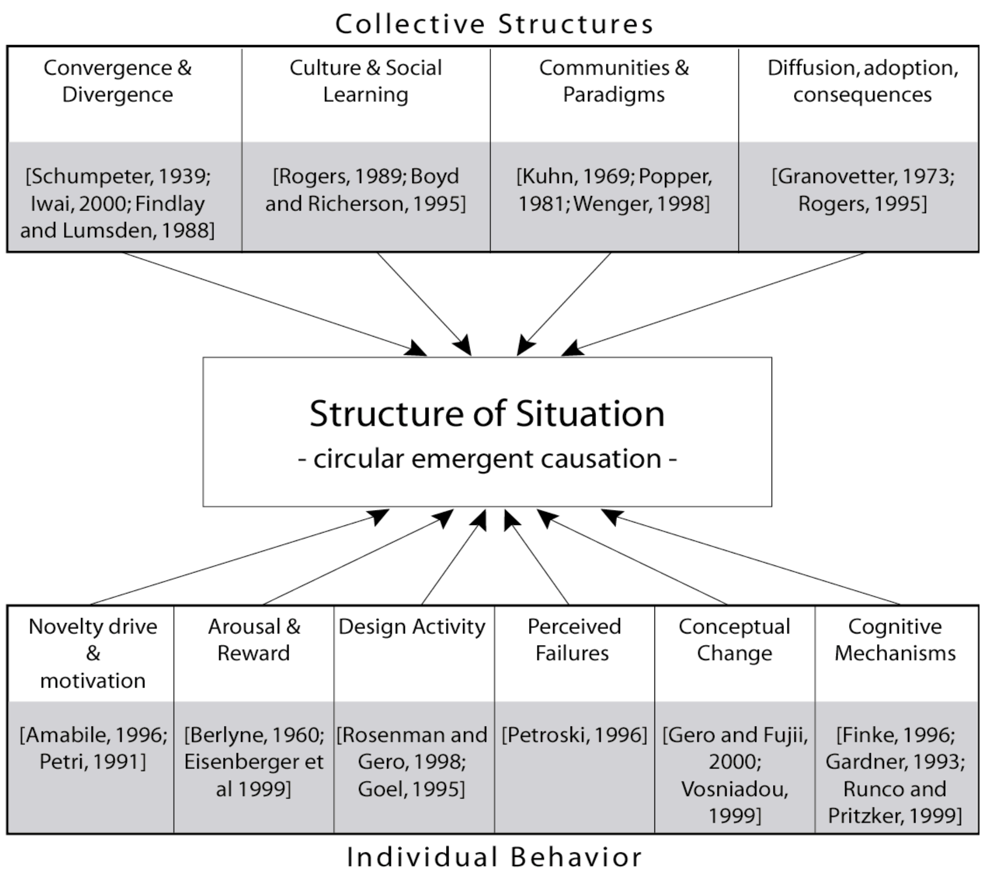


**Fig. 1.** Causation in the model of *design situations*. Top-down arrows represent causation from an illustrative set of collective structures whilst bottom-up arrows indicate bottom-up individual behavior determination. Both combine at the level of the situation where behavior takes place.

coupling of its internal characteristics with existing environmental conditions. Such a situation can be then studied in the way it facilitates the role of a change agent, being possible to characterize the creativeness of a situation from the outcome generated. The model proposed enables different experimentation scenarios. After a system run of an agent population, a situation-type can be identified and manipulated either by assigning that situation to an individual with different internal characteristics or by relocating the individual within its situation in a different environment.

It has been found in preliminary experimentation in elementary cellular automata models that individual traits alone do not directly determine social ascription due to situated factors, i.e. different individual behaviors may similarly trigger group changes whilst similar individual behaviors may have quite distinct group impact [Sosa and Gero, 2002a]. Further experimentation with the collective structures and individual mechanisms described in this paper is expected to provide insights into the way a situation can be characterized. A better understanding of the situated interaction by which a change agent emerges within a social environment would contribute to the inquiry on creativity and innovation.

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